NONLINEARITY OF MILITARY CONFLICTS FROM THE PERSPECTIVE OF COMPLEXITY SCIENCE

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Abstract*: The dynamic and interconnected relationships that arise in the study of military conflicts require, due to their high level of non-linearity, the use of sophisticated predictive modeling techniques. Thus, an acceptable estimate of the potential dangers that can significantly mark defeat or victory, becomes possible. In this study, we examine the cause-effect relationships of nonlinearity, nonlinear derivatives, nonlinear regression, and examine various emerging aspects of complexity science.*

Keywords: *complexity science, system, conflict, nonlinear, war, hybrid, emergence, entropy.*

Introduction

The science of complexity shows that there are social, physical or biological systems that can present behavioral phenomena that cannot be explained by conventional analyzes of the component parts of the systems. This emergent behavior occurs in many complex systems involving living organisms.

As an emerging research approach, complexity science is the study of a multivalent system. From the perspective of complexity science, in the research of complex systems, a non-linear appreciation of the various dynamic and interconnected relationships that appear in the operational complexity of conflicts, including military ones, is carried out.

In everyday speech, we say that an animate or inanimate system is complex when it is composed of many interacting components whose behavior or structure is difficult to understand. Sometimes a system can be structurally complex, like a mechanical clock, but behaves very simply, linearly. It is only a timing device and has a simple, regular and predictable

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behavior. On the other hand, there are also systems, whose structure is very easy to understand, but whose behavior is impossible to predict exactly, such as time or the Internet.

There are also some systems, such as the brain, that are complex in both structure and behavior.

Among the characteristics of the complexity paradigm, apart from nonlinearity, we mention: predictability-unpredictability, initial conditions, evolution, systemic sensitivity, self-organization, attractors, spatiality-temporality, classical and functional modeling, localization-generalization, induction-deduction, holism, synergy, dynamism.

Linearity versus nonlinearity

When examining cause-effect relationships, non-linearity is a quasi-constant problem[1]. Explanations of nonlinear events require complex modeling and testing of working hypotheses. Thus, if a certain relationship refers to a situation where there is a direct correlation between an independent variable and a dependent variable then we are referring to a linear relationship.

Any change in the independent variable will produce a measurable effect on the dependent variable such that the graph of a linear relationship between the independent and dependent[2] variables is a straight line. The same phenomenon does not occur in the case of a non-linear relationship that creates a curve and not a straight line.

The multiple variables that can influence the outcome of an armed action that has been decided by considering several options, the choice action regarding the expected outcome is characterized by a high non-linearity. For the purpose of an acceptable estimate, simulation techniques can be used to model the wide variety of variables with different parameters in order to assess the probability of success as well as the possible risks.

To model non-linear data in relation to independent variables (predictors) but also to explain the relationship between them, a common

[1] Hayes, A., „What Is Nonlinear? Definition, Vs. Linear, and Analysis" available at https://www.investopedia.com/terms/n/nonlinearity.asp, accessed at 10.12.2022.

[2] The independent variable is the one that changes or is controlled, being the cause of the phenomenology (the x-axis in a graph). The dependent variable is determined by the independent variable, being the effect that can be measured (ordinate y-axis in a graph).

form of regression analysis can be applied, namely non-linear regression. It uses the method of successive approximations to provide explanatory results.

Nonlinear regression models are much more complicated than linear ones because they involve considerable trial and error actions to define the results. As a direct definition, regression is a statistical measurement that determines the strength of the relationship between a dependent variable and a series of other variables.

Nonlinearity in the "grey area"

In the strategic competition determined by the conditions of hybrid warfare and in a poorly understood international arena, the "grey area" between peace and open conflict is increasingly highlighted.

According to Starling[3] the "grey zone" describes a set of activities that occur between peace (cooperation) and war (or armed conflict). A multitude of activities fall within this murky middle from nefarious economic activities to influence operations and cyber-attacks, to mercenary operations, assassinations and disinformation campaigns.

Activities in the "grey zone" are considered gradual campaigns by state and non-state actors that combine non-military and quasi-military instruments and fall below the threshold of armed conflict. They aim to hinder, destabilize, weaken or attack an adversary and are often tailored to the vulnerabilities of the target state.

Activities in the "grey zone"[4] have always been characteristic of competition between great powers: proxy wars, destabilizing insurgencies, information warfare.

The risk of conflict escalation being profound, nations seek to advance their national goals through aggression conducted covertly or with obscure attributions or justifications to achieve their goals.

[3] Starling, Clementine, G., Iyer, A., Today's wars are fought in the 'gray zone.' Here's everything you need to know about it" available at https://www.atlanticcouncil.org/-blogs/new-atlanticist/todays-wars-are-fought-in-the-gray-zone-heres-everything-you-need-to-know-about-it/, accessed on 10.12.2022.

[4] Idem.

It seems that while the US has been focusing on its conventional power, Russia and China occupied much of the grey area where they can pressure, coerce, destabilize and attack without risking conventional escalation. They have perfected their internal perception shaping capabilities through social media manipulation, censorship and absolute control over the media. Their national disinformation and influence operations target the Western public with impunity, resulting in an asymmetric advantage in information warfare, which is global in nature and strategic in effect.

Grey area operations seem to give a significant advantage to autocracies versus Western democracies. By the nature of their centralized systems, autocracies can afford to mobilize society-wide resources to execute proposed operations, while democracies are less effective at combining effective national responses.

In most activities in the "grey zone"[5] the advantage always goes to the first mover: the artificial islands built by China that now house military and intelligence capabilities, the annexation of Crimea by Russia and so on.

It appears that Western democracies are disadvantaged by their inability to predict the actions of their adversaries, their slow response time once these actions are identified, and their inhibition of synchronizing joint activities.

Conflict in dynamic nonlinearity

In the interactive dynamics between two rival powers, taking into account the economic factor and political constraints, paradoxical states and complex conflict trajectories may appear, determined both by the non-linear nature of the system and by the multiplicity of causes.

We illustrate the dynamic model of the interaction[6] between two nations subject to convex economic constraints and nonconvex political constraints.

According to this model, the economic constraint is a convex position of the sensible frontier between arms-versus-food opposition/complementarity: with given resources, a nation can produce

[5] Idem.

[6] Wolfson, M., Puri, A., & Martelli, M. (1992), „The Nonlinear Dynamics of International Conflict", *Journal of Conflict Resolution*, 36(1), 119–149, available at https://doi.org/-10.1177/0022002792036001005, accessed on 11.12.2022.

various combinations of civilian and military goods with diminishing returns to either product. The rate of exchange between civilian and military goods is negative and monotonically decreasing, i.e. without sign.

Political coercion is complex and reflects the choice between military power on one hand and the likelihood of peace on the other. Like economic agents, political leaders must choose between peace and power, so that sometimes the goals reinforce and sometimes they oppose each other.

The complexity of international politics stems from the fact that the acquisition of military capabilities could increase or decrease the probability of peace, so that the set of feasible state policies is not convex. Both the preponderance of power and the balance of power correspond to a high probability of peace.

The resulting non-convexity is the key to understanding the complex dynamics of international conflicts and it is likely that international politics is a non-linear system where small variations in initial conditions can lead to large, sometimes discontinuous and even chaotic changes.

The following example involves only two rivals and the assumption (Cournot) that only the immediate past of each affects the other's decision. We do not address the origins of the rivalry, nor do we analyze the course of events that may occur after the outbreak of hostilities.

In this sense we will follow two guidelines. The first of them refers to Richardson's traditionalist analysis[7] according to which international conflicts can be explained as the interaction of acts and threats that feed on themselves and generate a conflict trajectory. For prototyping purposes, it is convenient to make it easier to model this process as a Cournot-style dipole, to show that the single-period lag is equivalent to a system of first-order differential equations.

According to Wolfson, M., Puri, A., Martelli, the second guideline synthesizes two strategies for avoiding war.

[7] Wolfson, M.,1973, „A Dynamic model of present world conflict", *Papers of the Peace Science Society* 20:43-64.

The balance of power is epitomized by Intriligator and Brito (1984)[8] in their theory of the relationship between arms levels and the initiation of war, which suggests that war can be prevented when competing military power is held within a zone of mutual deterrence, so that both sides can inflict unacceptable losses on their opponent.

The preponderance of power is exemplified by that of Blainey (1988)[9]. This approach is consistent with the results of Organski and Kugler (1980)[10] and their successors (Houwelling and Siccama 1988)[11] who proposed a trichotomy: balance of power, "collective security" (predominance of power applied to alliances) and "transition of power". They adduce evidence in favor of the third alternative.

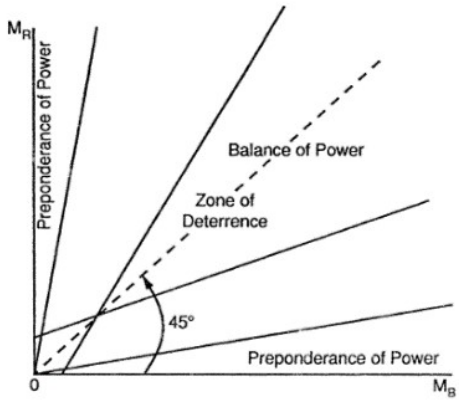

Figure no. 1: Balance of power-predominance of power
(after Wolfson, M., Puri, A., Martelli, M.)

[8] Intriligator, M. D. and D. L. Brito (1984), "Can arms races lead to the outbreak of war?" *Journal of Conflict Resolution,* 28: 63-84.
[9] Blainey, Geoffrey (1988), „The Causes of War", (3rd Edition) New York: The Free Press.
[10] Organski, A.F.K., and Jacek Kugler. (1980), „The War Ledger", Chicago: University of Chicago Press.
[11] Houweling, Henk W. and Jan G. Siccama. (1988). "Power Transitions as a Cause of War", Journal of Conflict Resolution 31:87-102.

The balance of power (Balance of power) is a region that surrounds the radius of 45° from the formula:

$$U_1 = U (C, H, P) \quad (1)$$

where U=social welfare or utility, C=civil goods, H=degree of hegemony over rival, P=probability of peace. If H=1 and the expected level of casualties is not low enough to deter attacks (Wolfson, Farrell, Gill and Shabahang 1992 apud Wolfson, M., Puri, A., Martelli, M., 1992), war breaks out. In this case, the trajectory of power distribution leaves the graphical area, while peace is maintained, even at high levels of armaments, as long as balance is maintained.

The transition of power has two meanings. In the first sense, it refers to the motivation for threatening the balance between a nation's desire for power and hegemony (defined as the relative military power of two rival countries, measured by their production of military goods and services). The second meaning refers to that intermediate point between balance and the preponderance of power. Under the conditions of political coercion, the probability of war is higher when neither the balance of power nor the preponderance of power is achieved.

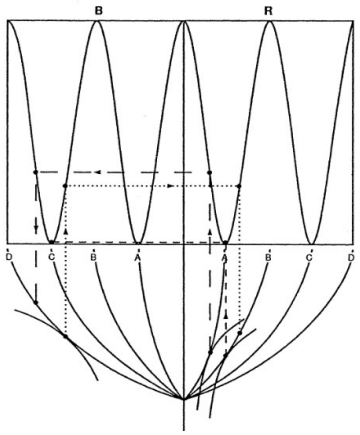

Figure no. 2 Dynamics of the balance between two countries B and R (after Wolfson, M., Puri, A., Martelli, M.)

Initially, country B adopts a high level of weaponry. Now, given its utility function (social welfare), country R adopts a subservient position at its frontier A, under the Cournot assumption that B will continue its high level of military activity. The supremacy of B means that R has the production possibility frontier A on the interior, and B is on the production possibility frontier D on the exterior. The big dashed line shows R's choices and expectations about B. It turns out that R was wrong about its opponent.

If B has the same functional utility as R, it will not respond with the expected allocation but will maximize its utility as shown by the dotted line. This line returns to R, which in turn responds along the small dashed line.

As a result of these dynamics, even if R had intended to adopt a submissive role, both sides ended up in a situation where the probability of peace is small.

When R chose submission, B reconsidered the level of military spending and preferred to increase spending on civilian goods. This legation of B increased R's chance for hegemony by choosing to increase its armaments production so that it weakened its civilian goods economy and virtually eliminated any chance for peace.

Against the background of the non-convex function of peace, the paradoxical dynamic resulting from the Cournot hypothesis according to which each nation reacts to the choices made by the opponent in the previous year. This means assigning the other nation a different utility function than its own. This course of action is not correct, their utility functions being identical, so the saraband continues.

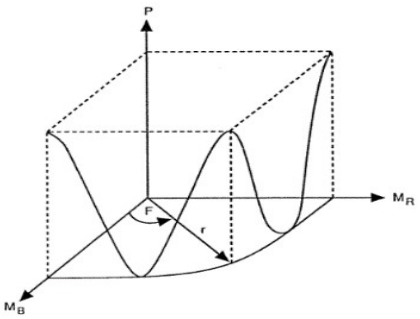

Figure no. 3 Probability of peace/war
(after Wolfson, M., Puri, A., Martelli, M.)

When P is considered to be a doubly differentiable function (Wolfson, M., Puri, A., Martelli, M.), we have:

$$P = P(MR,MB) \quad (2)$$

In polar coordinates P = P(r, F), P has a local maximum at the power balance with H = 1 at the 45° line where F = x/4, P(F) I(r)(b+ a cos8F) thus such that b> a > 0 and a + b < 1.

The restrictions on a and b guarantee that $1 \geq P \geq 0$ over the entire domain 0 to $\pi/2$. The trimodal function P can be generated for other cosine waves, such as cos10F, with F between 0 and $2\pi/5$. L controls the range of angle F required for the operation of the peace function through its three maxima.

Peace is related to hegemony H through F as the edge of a nonconvex set of policy alternatives. Hegemony increases with F because H = tanF and increases monotonically for F between 0 and $\pi/2$ and P is not monotonic because it depends on three local maxima of cosLF.

Conclusions

Approaching some relevant theories regarding peacekeeping in the light of political and economic constraints and revealing power balances can highlight the difficulties that political decision-makers may face.

The highlighted interaction pattern shows that economic forces tend to alleviate the stress of the system, bringing it towards equilibrium, while the variability comes from political tension.

We can conclude that the paradoxical appearances and the complexity of the conflicting trajectories under the conditions of the interactions of political-economic constraints, the nonlinearity of the system, the multiplicity of causes could generate convergent, chaotic, explosive, oscillating regimes.

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